TRIBOLOGICAL STUDIES ON ULTRA-FINE DIAMOND COMPOSITE COATINGS DEPOSITED ON TUNGSTEN CARBIDE

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Abstract

Ultra-fine diamond composite coatings were deposited onto the Co-cemented tungsten carbide (94wt.%WC-6wt.% Co) substrates via electron aided hot filament chemical vapor deposition (EAHFCVD). These diamond coatings have been tested in dry sliding against SiC particles reinforced aluminum-matrix composites materials (15% SiC PRAMC), metal copper wire core material (Cu-1) and metal aluminum wire core material (Al-0) by tribological pin-on-disc tests under a range of test conditions to evaluate the tribological performances of these ultra-fine diamond composite coatings. It was found that the friction coefficient of ultra-fine diamond composite coatings was remarkably decreased in comparison with that of uncoated carbides and normal diamond coatings after the initial period of rising rapidly. Furthermore, the friction coefficients between ultra-fine diamond composite coatings and SiC PRAMC, Cu-1, and Al-0 were measured as 0.122, 0.143, and 0.165 respectively during the steady-state period of friction. Thus, the friction coefficients of ultra-fine diamond composite coatings under the actual cutting environment of diamond-coated tools against above three materials were measured, and these data were analyzed based on physical and chemical theory. This fundamental work will be useful to the optimization of diamond CVD process and engineering applications of diamond coated tools in machining field.

INTRODUCTION

The adhesion of diamond thin film to the tungsten carbide substrate and the surface roughness of diamond thin film are the two key factors for diamond coated tools, which are becoming the main problems to be solved in process of cutting and drawing. Therefore, it is very important to obtain high quality diamond films with high adhesive strength and low surface roughness for the diamond coated tools. However, it is very difficult to obtain such high quality diamond films by conventional CVD methods. In the previous investigation [1-3], we have solved the problem of high surface roughness of polycrystalline diamond coatings by the deposition of ultra-fine diamond composite coatings. The tribological behaviour of ultra-fine diamond composite coatings plays an important role in determining the machining quality and work-life of tools, and which were investigated in this paper, and these data were analyzed based on physical and chemical theory.

EXPERIMENTAL DETAILS

Test Materials

Tungsten carbide (K10) was used as substrates. Tungsten carbide (K10) and Ultra-fine diamond composite coatings were used as discs, and15% SiC PRAMC, Cu-1 and Al-0 were used as pins respectively.

EAHFCVD Methods and Parameters

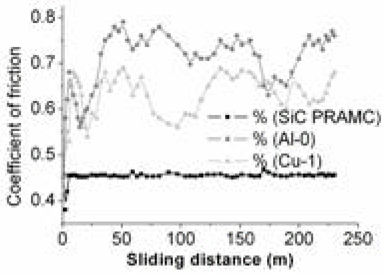
Before the deposition process, a new surface pretreatments for the WC-Co substrates were used step by step. The deposition experiments were carried out in the EAHFCVD reactor. Ultra-fine diamond thin films were continually fabricated by adjusting CVD process parameters to enhance the secondary nucleation greatly.

Tribological Testing Procedure

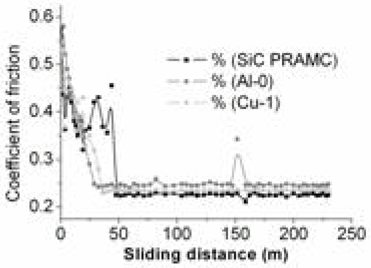
The tribological tests, conducted on a classical pin-on-disc tribometer under an ambient atmospheric and non-lubricated conditions, was used to evaluate the tribological behaviour of the ultra-fine diamond composite coatings, normal diamond coatings and uncoated tungsten carbides.

RESULTS AND DISCUSSION

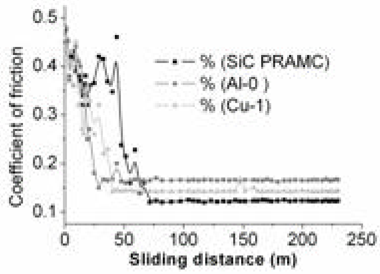
The surface morphology and quality of diamond coatings were characterized by SEM and Raman spectroscopy. In comparison with normal diamond coatings, diamond crystal of ultra-fine diamond composite coatings is fine and close in texture, and a layer of amorphous carbon similar to graphite was deposited on the surface of diamond crystal, which will conduce to reduce frictional coefficients of coatings against other materials. The presence of non-diamond component such as amorphous or graphitic carbon was investigated by Raman spectroscopy. The Raman shift of ultra-fine diamond composite coatings decreases in comparison with that of normal diamond coatings. Furthermore, the broad peak of sp^2-bonded carbon, which was attributed to graphite at approximately 1580 cm^{-1}, was also observed in ultra-fine diamond composite coatings. Due to the lubricating effect of graphitic debris, which can be easily sheared owing to its layered structure, and the graphitization occurs during sliding that has a lubricating effect, diamond coatings would obtain very low friction coefficients. Furthermore, the effect of the environment may be avoided by adopting the same experimental conditions including to the temperature and the relative humidity in order to investigate the friction coefficient of ultra-fine diamond composite coatings against 15 % SiC PRAMC, Cu-1 and Al-0 by tribological pin-on-disc tests. The frictional coefficients measured in tribological pin-on-disc tests for above three samples against bare WC, normal diamond coatings and Ultra-fine diamond composite coatings are shown in Fig.1. It indicates that frictional coefficients tended to be high and erratic during the initial rubbing period, and they settled down to a low and steady value afterwards. When above three samples were used to rub ultra-fine diamond composite coatings, all frictional coefficients reduced obviously due to the lubricating effect of graphitic debris of ultra-fine diamond composite coatings, which indicated ultra-fine diamond composite coatings are the more desirable tool coated materials than normal diamond coatings.



(a)



(b)



(c)

Fig.1 Frictional coefficients of the three samples rubbing against: (a) bare WC; (b) normal; (c) Ultra-fine;

CONCLUSIONS

Ultra-fine diamond composite coatings can drastically reduce the surface frictional coefficient during steady-state of rubbing in comparison with normal diamond coatings and bare tungsten carbides due to its especial physical and chemical performance such as the lubricating effect of graphitic debris in the machining process of 15% SiC PRAMC, Cu-1 and Al-0, as a result, which make ultra-fine diamond composite coatings become the most desirable tool coated material widely applied to the high speed machining non-ferrous difficult-to-cut materials in the field of automobiles industry, aeronautics and astronautics industry and effectively machining metal wire core material in the field of drawbench dies.

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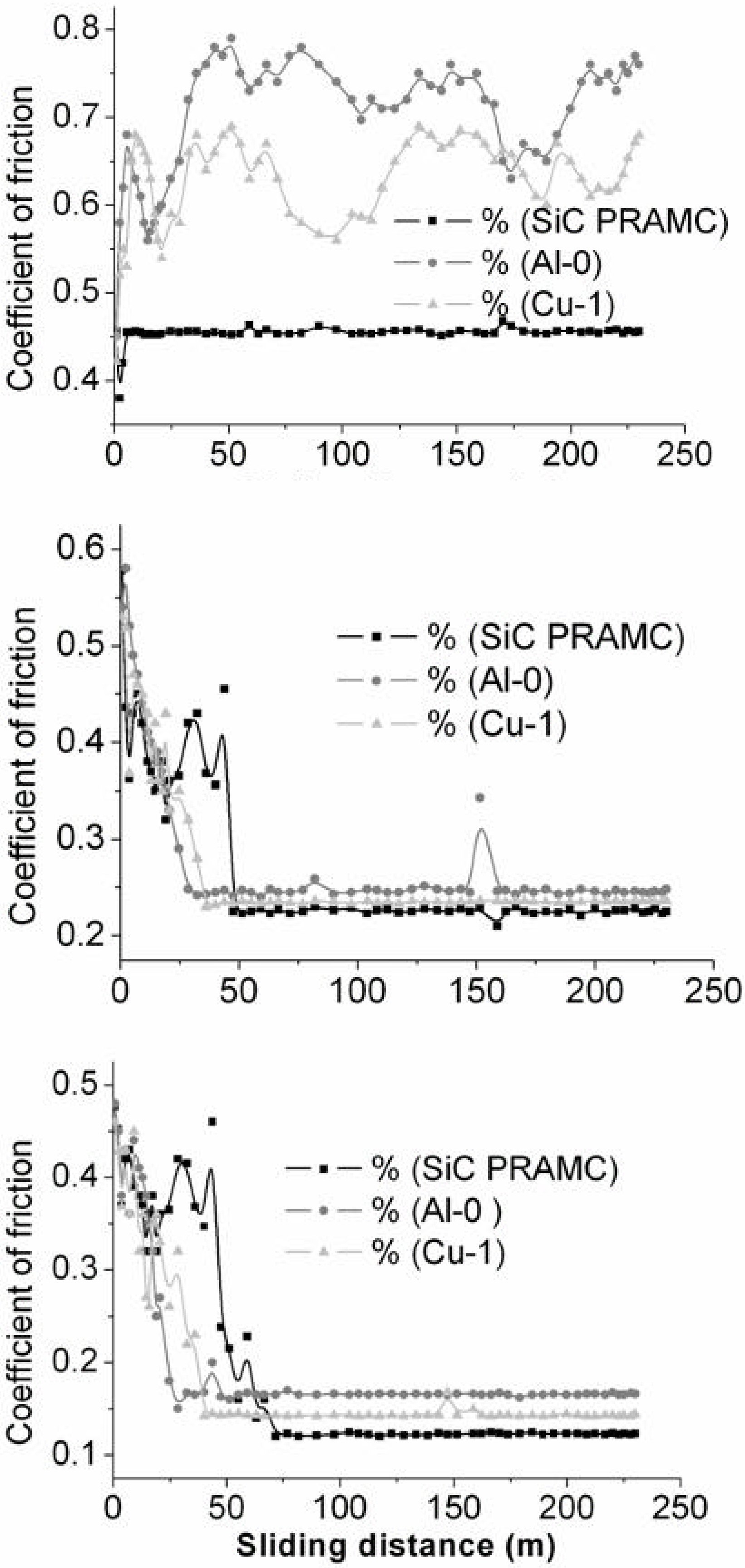

(a) bare WC;

(b) normal;

(c) Ultra-fine;